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REISSUE PATENT APPLICATION TRANSMITTAL

Address to: Assistant Commissioner for Patents Box Patent Application Washington, DC 20231	Attorney Docket No.	20030/40:2
	First Named Inventor	Michael G. West
	Original Patent Number	5,805,233
	Original Patent Issue Date (Month/Day/Year)	September 8, 1998
	Express Mail Label No.	EL639405590US

APPLICATION FOR REISSUE OF:

(check applicable box)

☒

Utility Patent

☐

Design Patent

☐

Plant Patent

APPLICATION ELEMENTS

- ☒ * Fee Transmittal Form (PTO/SB/56)
(Submit an original, and a duplicate for fee processing)
- ☒ Specification and Claims (amended, if appropriate)
- ☒ Drawing(s) (proposed amendments, if appropriate)
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(37 C.F.R. § 1.175)(PTO/SB/51 or 52) (unsigned)
- Original U.S. Patent
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(PTO/SB/53 or PTO/SB/54)
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- Original U.S. Patent currently assigned?
☒ Yes ☐ No
(If Yes, check applicable box(es))
☒ Written Consent of all Assignees (PTO/SB/53 or 54)
☒ 37 C.F.R. § 3.73(b) Statement ☒ Power of Attorney

ACCOMPANYING APPLICATION PARTS

- ☐ Foreign Priority Claim (35 U.S.C. 119)
(if applicable)
- ☒ Information Disclosure Statement (IDS)/PTO-1449 ☒ Copies of IDS Citations
- ☐ English Translation of Reissue Oath/Declaration
(if applicable)
- * Small Entity Statement filed in prior application, Status still proper and desired (PTO/SB/09-12)
- ☐ Preliminary Amendment
- ☒ Return Receipt Postcard (MPEP 503)
(Should be specifically itemized)
- ☒ Other: Applicant requests a transfer of drawings from the original patent file to the reissue application.

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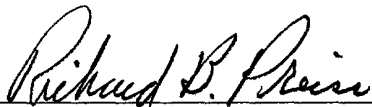
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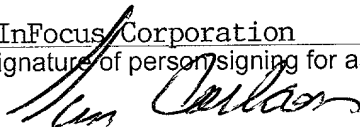
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REISSUE APPLICATION FEE TRANSMITTAL FORM						Docket Number (Optional)		
Claims as Filed - Part 1								
Claims in Patent	For	Number Filed in Reissue Application	(3) Number Extra	Small Entity		Other than a Small Entity		
				Rate	Fee	Rate	Fee	
(A) 20	Total Claims (37 CFR 1.16(j))	(B) 25	**** 5 =	x \$ _____ =		or	x \$ 18 = 90.00	
(C) 3	Independent Claims (37 CFR 1.16(i))	(D) 4	* 1 =	x \$ _____ =			x \$ 78 = 78.00	
Basic Fee (37 CFR 1.16(h))						\$ _____	\$ 690.00	
Total Filing Fee						\$ _____	OR \$ 858.00	
Claims as Amended - Part 2								
	(1) Claims Remaining After Amendment		(2) Highest Number Previously Paid For	(3) Extra Claims Present	Small Entity		Other than a Small Entity	
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Total Claims (37 CFR 1.16(j))	***	MINUS	**	*	x \$ _____ =		or	x \$ _____ =
Independent Claims (37 CFR 1.16(i))	***	MINUS	*****	=	x \$ _____ =			x \$ _____ =
Total Additional Fee						\$ _____	OR \$ _____	
<p>* If the entry in (D) is less than the entry in (C), Write "0" in column 3.</p> <p>** If the "Highest Number of Total Claims Previously Paid For" is less than 20, Write "20" in this space.</p> <p>*** After any cancellation of claims</p> <p>**** If "A" is greater than 20, use (B - A); if "A" is 20 or less, use (B - 20).</p> <p>***** "Highest Number of Independent Claims Previously Paid For" or Number of Independent Claims in Patent (C).</p>								
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<u>9/8/00</u> Date		 Signature of Applicant, Attorney or Agent of Record						
<u>Richard B. Preiss, Registration No. 36,640</u> Typed or printed name								

REISSUE APPLICATION BY THE ASSIGNEE, OFFER TO SURRENDER PATENT		Docket Number (Optional) 20030/41:2
This is part of the application for a reissue patent based on the original patent identified below.		
Name of Patentee(s): Michael G. West		
Patent Number 5,805,233	Date Patent Issued September 8, 1998	
Title of Invention METHOD AND APPARATUS FOR AUTOMATIC PIXEL CLOCK PHASE AND FREQUENCY CORRECTION IN ANALOG TO DIGITAL VIDEO SIGNAL CONVERSION		
<u>InFocus Corporation</u> is the assignee of the entire interest in the original patent.		
I offer to surrender the original patent.		
<input checked="" type="checkbox"/> A certificate under 37 CFR 3.73(b) is attached.		
I am authorized to act on behalf of the assignee.		
I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under 18 U.S.C. 1001 and that such willful false statements may jeopardize the validity of the application, any patent issued thereon, or any patent to which this declaration is directed.		
Name of assignee <u>InFocus Corporation</u>		
Signature of person signing for assignee 		Date 9/6/00
Typed or printed name and title of person signing for assignee Timothy M. Carlson, Director of Legal Affairs		

STATEMENT UNDER 37 CFR 3.73(b)

Applicant/Patent Owner: InFocus Corporation

Application No./Patent No.: 5,805,233 Filed/Issue Date: September 8, 1998

Entitled: METHOD AND APPARATUS FOR AUTOMATIC PIXEL CLOCK PHASE AND FREQUENCY CORRECTION IN ANALOG TO DIGITAL VIDEO SIGNAL CONVERSION

InFocus Corporation, a n Oregon Corporation
(Name of Assignee) (Type of Assignee, e g , corporation, partnership, university, government agency, etc)

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The undersigned (whose title is supplied below) is empowered to sign this statement on behalf of the assignee.


Date

9/6/00
Signature

Timothy M. Carlson
Typed or printed name

Director of Legal Affairs
Title

United States Patent [19]

West

[54] METHOD AND APPARATUS FOR
AUTOMATIC PIXEL CLOCK PHASE AND
FREQUENCY CORRECTION IN ANALOG
TO DIGITAL VIDEO SIGNAL CONVERSION

[75] Inventor: Michael G. West, Portland, Oreg.

[73] Assignee: In Focus Systems, Inc., Wilsonville,
Oreg.

[21] Appl. No.: 614,511

[22] Filed: Mar. 13, 1996

[51] Int. Cl.⁵ H04N 5/12

[52] U.S. Cl. 348/537; 348/536; 348/540

[58] Field of Search 348/536, 537,
348/538, 539, 540, 541, 542, 543, 544,
556, 558, 500, 501, 510, 511, 512; 358/158;
331/20; H04N 5/04, 5/12

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Primary Examiner—John K. Peng

Assistant Examiner—Chris Grant

002050 "5E-409360



[11] **Patent Number:** 5,805,233
[45] **Date of Patent:** Sep. 8, 1998

Attorney, Agent, or Firm—Timothy M. Carlson

[57] **ABSTRACT**

A method for producing a digital video signal from an analog video signal, the analog video signal including an analog video data signal that is raster scanned in lines across a CRT screen to form consecutive frames of video information, the raster scanning controlled by use of a horizontal synchronizing signal (H_{sync}) that controls a line scan rate, and a vertical synchronizing signal (V_{sync}) that controls a frame refresh rate, to produce consecutive frames of video information, wherein the digital video signal is produced by generating a pixel clock signal with pixel clocks for repetitively sampling instantaneous values of the analog video data signal, and digitizing the analog video data signal based on the pixel clock sampling. An expected width E , measured in number of pixel clocks, of a video image producible by the analog video signal is estimated, and an actual width W , measured in number of pixel clocks, of the video image producible by the analog video signal is calculated. The actual width W is compared with the expected width E . When E does not equal W , at least one of a frequency component and a phase component of the pixel clock signal is adjusted until E equals W .

20 Claims, 5 Drawing Sheets

METHOD AND APPARATUS FOR AUTOMATIC PIXEL CLOCK PHASE AND FREQUENCY CORRECTION IN ANALOG TO DIGITAL VIDEO SIGNAL CONVERSION

FIELD OF THE INVENTION

The present invention pertains to converting from an analog video signal to a digital video signal, and in particular to automatically adjusting phase and frequency of a clock for converting from an analog signal to a digital signal, and particularly for.

BACKGROUND AND SUMMARY OF THE INVENTION

Presentations using multimedia projection display systems have become popular for purposes such as sales demonstrations, business meetings, and classroom sessions. In a common mode of operation, multimedia projection display systems receive analog video signals from a personal computer (PC). The video signals represent still, partial-, or full-motion display images of the type rendered by the PC. The analog video signals are converted into digital video signals to control a digitally-driven display object, such as a transmissive liquid crystal display (LCD), to form the display images for projection onto a display screen.

Two common types of multimedia projection display systems are LCD projectors and LCD projection panels. An LCD projector includes a transmissive LCD, a light source, and projection optics to form and project display images in the manner describes above. An LCD projection panel includes a similar transmissive LCD to form the display image, but operates with a conventional overhead projector (OHP) having a light source and projection optics, to project the display image onto a display screen. Examples of such LCD projectors and LCD projection panels are sold under the respective trademarks LITEPRO and PANELBOOK by In Focus Systems, Inc. of Wilsonville, Ore., the assignee of the present application.

One desirable feature for multimedia display systems is compatibility with the various analog video signal modes generated by various PC's. These modes generally range from 640x480 to 1600x1200 resolutions provided at image refresh rates of 60 to 100 Hz. The resolution expresses the number of horizontal and vertical pixel elements that can be turned on and off. Given the variety of resolution modes, multimedia display systems include an interface that converts analog video signals of various modes to digital video signals capable of controlling the LCD.

In general, analog video signals comprise an analog image data signal for each of the primary colors red, green and blue, and digital timing signals, which may include a pulsed horizontal synchronizing signal (H_{sync}) and a pulsed vertical synchronizing signal (V_{sync}), or a composite sync signal. The individual analog color signals are generated from bit data in a memory portion of the PC, using three digital-to-analog (D/A) converters, one for each of red, green and blue. FIG. 1a shows an exemplary analog signal waveform 1, with plateau regions (pixel data components) that correspond to the color level of individual pixels of the image display. Consecutive pixel data components are connected by signal transition regions. The digital timing signal controls the raster-scanning of the analog video data signals across the monitor screen. The H_{sync} pulse controls the horizontal raster scan rate, and the V_{sync} pulse controls the image (or frame) refresh rate. In the case of a composite sync signal, a conventional sync separator is first used to obtain the horizontal and refresh signals.

As shown in FIG. 1d, each video frame 9 is usually produced to have a central active video region 11 surrounded by an inactive ("blanked") margin 13. The resolution refers to only the pixels in the active video region.

Because the LCD used in multimedia display systems require digital video signals, either the LCD or the system normally has an analog to digital (A/D) signal converter for converting the PC-generated analog video signals into a digital format suitable for driving the LCD. The A/D signal converter is usually combined with a phase-locked loop (PLL), which may comprise a phase comparator, a low-pass loop filter, and a voltage-controlled oscillator (VCO) formed in a loop to generate a feedback signal that locks into H_{sync} . In order to generate a selected multiple n of clock pulses for each period of H_{sync} , a divide-by- n counter is added to the feedback loop between the VCO output and the phase comparator.

An example of a pixel clock waveform 4 is shown in FIG. 1a. The number n of individual pixel pulses per H_{sync} pulse may be set by reference to the resolution mode of the analog video source. To set the resolution mode, certain characteristics of the analog video signal, such as H_{sync} and V_{sync} , may be used to refer to a mode look-up table stored in the display system CPU. The number n should be set to equal the number of pixel data components in each horizontal line of the scanned analog signal, including those active video data region 11 and the blanked margin regions 13 (see FIG. 1d) on either side of the active region. For example, for a screen resolution of 640x480, n may be set at about 800 to include the blanked regions on either side of the 640 pixel-wide active video data region. Thus, the pixel clock would sample the continuous stream of analog image data 800 times along each horizontal line of the frame.

FIG. 1a shows the desired relationship between the analog video data signal 1 and the pixel clock signal 4. The number n of pixel clocks 5 is set to establish a one-to-one relationship between pixel clock pulses 5 and pixel data components 2 of the analog data signal 1. This one-to-one relationship requires that the pixel clock signal frequency be equal to the analog video data signal frequency. Under this relationship, each pixel data component 2 of the analog signal is sampled by a single pixel clock pulse 5, which reads the instantaneous voltage value of the pixel data component so that it can be digitized. Since the pixel clock pulses 5 have "jitter" zones 6 at their leading and trailing edges, the clock pulses 5 should be registered with the centers of the pixel data components 2, so that the sampling is not randomly pushed by the jitter into the transition regions 3 of the analog video signal.

The stream of digitized values form the digital video data signal, which is addressed to the LCD to appropriately set LCD pixels at blank (black) or selected activated (non-black) status to replicate the image defined by the analog video signal.

Unfortunately, such A/D conversion is often imperfect due to errors in the pixel clock sampling of the analog signal. Such sampling imprecision gives rise to frequency (also known as "tracking") and "phase" errors, both of which may degrade the quality of the LCD image.

Referring to the analog video signal 1 and pixel clock signal 4' in FIG. 1b, tracking error results from the number n of pixel clocks being improperly set. As discussed above, the number n of pixel clocks should be equal to the number of pixel data components 2 of each horizontal line of analog video data signal. In FIG. 1b, the improper setting of n results in the pixel data components 2 not being sampled at

In accordance with a preferred method of the present invention, a digital video signal is produced from an analog video signal which includes an analog video data signal that is operable to be raster scanned in lines across a CRT screen to form consecutive frames of video information, the raster scanning controlled by use of a horizontal synchronizing signal (H_{sync}) that controls a line scan rate, and a vertical synchronizing signal (V_{sync}) that controls a frame refresh rate, to produce consecutive frames of video information. The digital video signal is produced by generating a pixel clock signal with pixel clocks for repetitively sampling

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 6 depicts an exemplary configuration of video data on a display object in accordance with the present invention.

As shown in FIG. 2, for purposes of video signal transmission, the multimedia source PC 12 is connected to the projection display system 10 through a video source cable 30 which is shown in exploded schematic form. The cable 30 is of conventional design and includes multiple distinct conductors that are shielded together, including

The LCOMP has a LHPC input 82 that is connected through bus 60 to the HPC output 61, an LREG input 84 that

is connected through a bus 86 to the LEFT REG output 70, and an LCOMP output 88. The RCOMP has a RHPC input 90 that is connected through bus 60 to the HPC output 61, an RREG input 92 that is connected through a bus 94 to the IRIGHT output 80, and a RCOMP output 96.

As shown in FIGS. 4 and 5, a pixel value calculator 97 has inputs receiving each of the RGB video data signal channels 56a, 56b, 56c. The RGB video data signals are connected in parallel to an "OR" gate 99a, and are connected to a 4:1 multiplexer 99b. The output of the OR gate 99a is also connected to the multiplexer 99b. The output 101 of the pixel value calculator is connected through bus 103 to a pixel data comparator (PIXCOMP).

The PIXCOMP has a threshold value input 98 connected to a threshold value register (THRESH REG), and a pixel value input 100 connected to the pixel value calculator 97. The PIXCOMP has an output 102 connected to a first input 104 of a left AND gate (LGATE). The LGATE has a second input 106 that is connected to the LCOMP output 88, and a LGATE output 108 that is connected to the LLOAD input 66 of the LEFT REG. The PIXCOMP output is also connected to a first input 110 of a right "AND" gate (RGATE). The RGATE has a second input 112 that is connected to the RCOMP output 96, and an output 114 that is connected to the RLOAD input 76 of the RIGHT REG.

A left edge status register (LEFT STATUS) has an input 116 connected through bus 86 to the LEFT REG output 70, a LCLOCK input 118 connected to the pixel clock signal, a LLOAD input 120 connected to the V_{sync} frame advance signal, and an output 122 connected through bus 42 to the microcontroller (FIG. 2). A right edge status register (RIGHT STATUS) has an input 124 connected through bus 94 to the RIGHT REG output 80, a RCLOCK input 126 connected to the pixel clock signal, a RLOAD input 128 connected to the V_{sync} frame advance signal, and an output 130 connected through bus 42 to the microcontroller (FIG. 2).

Turning to the signal path to the LCD shown in FIG. 2, the line advance conductor 53, the digital video data signal channels 56a, 56b, 56c, and the frame advance conductor 58 are connected to an input port of a window random access memory (WRAM) 132. The WRAM has an output port connected to an LCD control module 134. The LCD control module is connected to the LCD 28. The LCD is preferable a 6.4 inch active matrix LCD, such as model LQ64P311 made by Sharp.

Operation

The operation of the preferred embodiment will now be explained. The display system 10 determines the resolution mode by a firmware program that uses the mode identification counter 43. H_{sync} is input through conductor 45 to the mode identification counter 43, and the number of 50 MHz counter clocks over twenty H_{sync} pulses is counted. In this way, an average number of clocks per line is obtained. V_{sync} is input through conductor 47 into the mode identification counter 43, and the number of lines for each V_{sync} pulse is obtained. The firmware then accesses a look-up table that determines resolution based on the number of 50 Mhz clocks per twenty lines, and number of lines per frame. An exemplary look-up table showing a few common non-interlaced 60 Hz video modes is as follows:

TABLE 1

$\gamma_{\text{sync}}(\text{Hz})$	Number of 50 MHz Clocks/20 lines	Lines/Frame	Resolution	Pixel Clocks/ Line (n)
60 Hz	31778	525	640×480	800
60 Hz	24400	628	800×600	1056
60 Hz	20677	806	1024×768	1344
60 Hz	15631	1086	1280×1024	1696

Thus, for exemplary values of 31778 50MHz clocks in twenty lines, and 525 lines per frame, the look-up table determines a resolution of 640×480 , with a number n of pixel clocks per line of 800. The expected width (in pixels) of the active video region II (see FIG. 1d) is initially set at the horizontal component of the resolution (e.g. 640).

It is to be understood that such number n is an initial guess, and that a range of initial n values will work, due to the iterative corrective nature of the present invention. Accordingly, n may be determined in other ways, such as by multiplying the horizontal resolution by a constant slightly larger than 1.0. It is also to be understood that the preferred look-up table will cover modes from 640×480 to 1600×1200 resolution, and from 60 Hz to 100 Hz frame refresh rates. Moreover, other ways of determining the resolution are possible, such as by using the number of lines per frame to determine the vertical and horizontal resolution.

Digitization of the analog video data signals occurs based on the n pixel clocks per line. Referring to the PLL 20, the VCO 50 generates the pixel clock signal, and the microcontroller 16 sets the counter 22 to generate a feedback pulse (i.e. line advance signal) once every n pixel clocks. Once n is selected, the PLL automatically adjusts to produce a line advance signal frequency corresponding to H_{sync} , and a pixel clock signal having a frequency of n times the line advance frequency.

The PLL works by the phase comparator 46 receiving the H_{sync} signal from the delay device 18 through conductor 44, and receiving the feedback pulse signal through the feedback loop 52. The phase comparator 46 compares the frequencies of the H_{sync} and the feedback pulse signal, generating an output voltage that is a measure of their phase difference. If the feedback pulse frequency does not equal the H_{sync} frequency, the phase difference signal causes the VCO pixel clock frequency to deviate so that the feedback pulse frequency of the counter 22 deviates toward the H_{sync} frequency.

The feedback pulse signal (line advance signal) of the counter 22 is directed to the ASIC 26 through a conductor 53, and the pixel clock signal of the VCO 50 is directed to the ASIC 26 and the A/D converter 24 through conductor 54. The line advance signal and V_{sync} are conditioned to be one clock pulse in duration, through the use of a pulse edge detection circuit or the like.

The A/D converter 24 samples (reads) the instantaneous voltage value of the analog video data signal at the leading edge of each of the pixel clocks, thereby generating a series of sampled data signal values. The A/D converter then quantizes the sampled values by matching each value to one of a series of preselected voltage amplitude levels, which have corresponding numerical values. These numerical values are then represented digitally and coded to establish 8-bit data for each of the colors red, green and blue. The three eight-bit color data signals are input through the three respective color data signal channels 56a, 56b, 56c to the

edge detection circuit 26. At the LCD, the coded color data signal set pixels at blank (black) or specific activated (non-black) status corresponding to the sampled voltage level.

The actual width W of the active video region 11 (FIG. 1d) is then determined by the image edge detection circuit shown in FIG. 4. The actual width W is measured in number of pixel clocks equal to: ((the right-most active pixel in a frame)-(the left most-active pixel in a frame)+1). Thus, W is a measure of the total number of pixels across the active video region of a frame of video data. The pixel clock positions referred to in the following are the sampling positions of pixel clocks along the lines of analog video data in a frame.

The PIXCOMP compares the threshold value with the value of each pixel of the pixel data signal, and generates a binary "yes" if the pixel value is greater than the threshold value. The pixel value calculator 97 determines the value of each pixel by grouping the twenty-four total bits of each pixel together in eight groups of individual red, green and blue bits. Each of these groups of three bits is passed through the "OR" gate 99a, and the results of all of the eight "ored" groups and the digital RGB data signals are multiplexed in the 4:1 multiplexer 99b to establish a value for each pixel. It is contemplated that the pixel value may be set in various other ways, including setting a separate value for one or each of the RGB digital data signals.

The pixel value is compared against a selected threshold value at the PIXCOMP. If the sum is greater than the threshold value, a binary "yes" signal is delivered to the LGATE and RGATE, designating the pixel as active. If the pixel value sum is less than the threshold value, the PIXCOMP generates a binary "no", indicating the pixel as inactive.

The LCOMP compares the instantaneous pixel position generated by the HPC with a pixel position stored in the LEFT REG. At the beginning of each frame, the LEFT REG is preferably initialed at the far right pixel position of the video region (i.e., the right edge of the inactive margin region 13 in FIG. 1d). The LCOMP outputs a binary "yes" to the LGATE when the instantaneous HPC pixel position is less than the pixel position stored in the LEFT REG. When the PIXCOMP is simultaneously outputting a "yes", the LGATE signals the LEFT REG through the LLOAD input 120 to replace the stored LEFT REG pixel position with the instantaneous HPC pixel position.

Similarly, the RCOMP compares the instantaneous pixel position generated by the HPC with a pixel position stored in the RIGHT REG. At the beginning of each frame, the RIGHT REG is preferably initialed at the far left pixel position of a video region (i.e., the left edge of the inactive margin region 13 in FIG. 1d). Referring again to FIG. 4, the RCOMP outputs a binary "yes" to the RGATE when the instantaneous HPC pixel position is greater than the pixel position stored in the RIGHT REG. When the PIXCOMP is simultaneously outputting a "yes", the RGATE signals the RIGHT REG through the RLOAD input to update the stored RIGHT REG pixel position with the instantaneous HPC pixel position.

At the end of each frame, V_{sync} signals the LEFT STATUS and RIGHT STATUS to update the respective stored left edge and right edge pixel positions. The stored left and right pixel positions are then read by the microcontroller, and the actual width W (in pixels) of the active video region 11 of the frame 9 (FIG. 1d) is calculated by subtracting the left edge pixel position stored in LEFT STATUS from the right edge pixel position stored in RIGHT STATUS.

Once the actual width W is determined, the microcontroller compares it with the expected width E . If $E=W$, then the clock phase and the number n of clocks per line is correct. In other words, at $E=W$, each discrete data region (plateau) of the analog video data signal is aligned with and sampled by a pixel clock, resulting in error-free digitization of the analog video data signal. In this case, n and the pixel clock phase are left unchanged for the scanning of the next frame.

If $W>E+1$ or $W<E$, then the number n of clocks per line is incorrectly set, resulting in tracking error. To correct such tracking error, a the number n of pixel clocks is adjusted to a new number $n'=n \cdot (E/W)$. The original n is replaced by the adjusted n' , and the next frame is scanned as set forth above. Such adjustment of n is iteratively repeated every frame until $W=E$ or $W=E+1$. Put another way, if the actual width W is larger than the expected width E , the number of pixel clocks n per line is decreased, (i.e. the period of each pixel clock is increased, and the frequency of the pixel clock signal is decreased), so that the width of the E pixel clocks is effectively spread out to precisely register with the active pixel data region. Conversely, if the actual width W is smaller than the expected width E , the number of pixel clocks n per line is increased, so that the width of the E pixel clocks is effectively contracted to register precisely with the active pixel data region of the analog video data signal.

Once the tracking error is corrected, any phase error is corrected. As discussed above, if $W=E$, the number of pixel clocks n per line is correctly configured, and no phase error exists. However, if $W=E+1$, phase error is present, resulting in noise in the video display. Referring to FIG. 1, phase error occurs because of the "jitter" zones present in the leading and trailing edges of clock pulses. Even if the pixel clock signal frequency is equal to the analog video data signal frequency, phase error noise will occur if the jitter zone on the leading edge of the pixel clock waveform overlaps with a transition zone on either side of plateau regions of the analog video data waveform.

To correct the phase error when $W=E+1$, microcontroller signals the programmable delay to adjust the pixel clock signal phase by a selected iterative amount for each of a series of subsequent frames. The pixel clock phase iteration proceeds until the frame phase error condition passes from $W=E+1$ through a subseries of frames without phase error (i.e. $W=E$), and back to a frame with a phase error condition of $W=E+1$. The resulting series of W values is stored in the microcontroller. The stored series of W values are then examined to identify the subseries of consecutive frames in which $W=E$. A phase corrected frame in the center of the subseries is then selected, and the programmable delay is signaled to set the pixel clock phase at the phase of the phase corrected frame. Thus, the phase is set so that the pixel clock leading edges are located in the middle of the analog video signal pixel components, in order to consistently avoid sampling in transition regions.

The digital video signals output from the video capture circuit 14 are manipulated by the WRAM 132 and LCD control module 134 to appropriately control the LCD 28. For instance, the WRAM and LCD control module may "flip" the digital video signals as appropriate for different multimedia display system 10 applications, such as front lighting and back lighting of a display screen. The WRAM and LCD control module may also serve to manipulate interlaced video modes into noninterlaced form appropriate for controlling the LCD.

It is also noteworthy that the method and apparatus of the present invention can be used to properly horizontally

position the active video region 11 (FIG. 1d) on the LCD. In this application, the value of LEFT STATUS may be used to determine when video data begins to be stored by the WRAM 132. Thus, no data is stored for the blanked margins on either side of the active video region, eliminating the possibility that spuriously activated analog pixel components in the blanked margin region will be transferred to the LCD.

EXAMPLE

An exemplary image edge detection method will now be described in conjunction with the exemplary screen image shown in FIG. 6. The determination of the actual image width W for a single frame will be described, with the assumption that the original analog image has a resolution of 640x480. Referring to the look-up table, the number of lines/frame is 525, and n is 800. In this example, the pixel position will be designated by Cartesian coordinates corresponding to the horizontal line position and vertical line of the pixel.

The exemplary screen image 140 is a diamond-shape 142 above a horizontal menu bar 144. A margin of blanked pixels 146 (bounded by a dashed line) extends along the sides and the top and bottom of the active image region 148. The diamond has an upper point at horizontal pixel position 400, 20. The diamond widens to a pair of side points on the same horizontal pixel line at respective pixel positions 200, 300 and 600, 300. The diamond has a lower point at horizontal pixel position 400, 475. The menu bar immediately below the diamond has upper left and right edges at horizontal pixel positions 80, 475 and 720, 475 respectively.

Prior to imaging, the LEFT REG is initialized at 800 and the RIGHT REG is initialized at 0. The frame scan begins with blanked pixel data that is advanced line by line down through the blanked upper margin of the total data region. Since none of the blanked pixel values P are above the threshold value T, the LEFT REG and RIGHT REG are not updated.

The first active pixel is sampled at the diamond upper point at 400, 20. At this point the $HPC < LEFT\ REG$ and the $HPC > RIGHT\ REG$, so that both LEFT REG and RIGHT REG update to 400. The LEFT REG updates toward the left and the RIGHT REG updates toward the right as the frame scan moves downward through upper diagonal section 150 of the diamond. The LEFT REG and RIGHT REG are respectively updated to 200 and 300 at the diamond side corners, and then are not further updated as the frame scan moves through narrowing lower diagonal section 152 of the diamond.

As the frame scan moves onto the menu bar area, active pixel data begins at $HPC=80$. Since $HPC=80 < LEFT\ REG=200$, the LEFT REG updates to 80. As the scan moves past $HPC=600$ toward the right edge of the menu bar, the RIGHT REG updates rightward until $RIGHT\ REG=720$ at the right edge of the menu bar. The LEFT REG and RIGHT REG do not further update as the frame scan moves down through the menu bar and the lower blanked area.

At the end of the frame, V_{sync} signals the LEFT STATUS and RIGHT STATUS to update the left and right edge positions respectively to 80 and 720. The microcontroller then calculates $W=RIGHT\ STATUS-LEFT\ STATUS=640$. Thus, in this example $W=E=640$, and no tracking or phase error correction is required. Of course, if $W>E+1$ or $W<E$, an adjusted number n' of pixel clocks would be calculated as described above. If $W=E+1$, then pixel clock phase correction as described above would be initiated.

Although the present invention has been described in connection with a preferred embodiment thereof, it is to be

understood that such preferred embodiment is exemplary only. It will be appreciated by those skilled in the art that additions, deletions, modifications and substitutions may be made to the described preferred embodiment without departing from the spirit and scope of the invention. For instance, the present invention is applicable to any digital display device that converts analog video signals into digital video signals for controlling a digital display object. Such a digital display object, in addition to various types of LCD, may be a light valve of diffraction grating, micro-mirror, or other type. The analog video source may also be a VCR, a computer workstation, or other device. Moreover, the edge detection circuit can also be utilized to detect the upper and lower vertical edges of an image. Accordingly, the present invention should be interpreted broadly in reference to the appended claims.

What is claimed is:

1. A method for recovering a correct phase and frequency clock for an analog video signal that is converted for display on a digital display object having pixels arranged in lines and columns, the analog video signal including an analog video data signal that is operable for raster scanning in lines across a CRT screen to form consecutive frames of video information, the raster scanning controlled by timing signals that control a line scan rate and a frame refresh rate, to produce consecutive frames of video information, comprising the steps of:

converting an analog video signal to a digital video signal;
estimating an expected width of an image producible by the analog video signal;
determining an actual width of a image producible by the digital video signal;
iteratively adjusting the digital video signal until the actual width equals the expected width.

2. The method of claim 1, including the steps of:

generating a pixel clock signal that samples the analog video signal in order to convert the analog video signal to the digital video signal; and

iteratively adjusting at least one of frequency and phase of the pixel clock signal in order to iteratively adjust the digital video signal.

3. The method of claim 2, including the step of:

adjusting the frequency of the pixel clock signal before adjusting the phase of the pixel clock signal.

4. A method for producing a digital video signal from an analog video signal, the analog video signal including an analog video data signal that is operable for raster scanning in lines across a CRT screen to form consecutive frames of video information, the raster scanning controlled by timing signals that control a horizontal line scan rate and a frame refresh rate, to produce consecutive frames of video information, comprising the steps of:

generating a pixel clock signal with pixel clocks for repetitively sampling instantaneous values of the analog video data signal;

digitizing the analog video data signal based on the pixel clock sampling;

estimating an expected width E, measured in number of pixel clocks, of an expected video image producible by the analog video signal;

calculating an actual width W, measured in number of pixel clocks, of an actual video image producible by the analog video signal;

comparing the actual width W with the expected width E, and when E is unequal to W;

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setting a total number n of pixel clocks that read the analog video data signal along each horizontal line;
 determining an expected number E of pixel clocks from an expected left-most pixel clock in a frame that reads a left-most value of the analog video data signal that is greater than a selected threshold value, to an expected right-most pixel clock in the frame that reads a right-most value of the analog video data signal that is greater than the selected threshold value, the expected number E indicating an expected width of active analog video data;
 determining an actual number W of pixel clocks from an actual left-most active pixel clock in the frame that reads a left-most actual value of the analog video data signal that is greater than the selected threshold value, to an actual right-most pixel clock in the frame that reads a right-most actual value of the analog video data signal that is greater than the selected threshold value, the actual number W indicating an actual width of active analog video data; and
 comparing the actual number W with the expected number E .

16. The method of claim 15, including the steps of:
 when one of $W > E + 1$ and $W < E$, calculating an adjusted total number n' of pixel clocks that read instantaneous analog video data signal values across each line of analog video signal $n' = n(E/W)$;
 substituting n' for n for a next frame; and
 redetermining the actual number W of pixel clocks for the next frame.

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17. The method of claim 15, including the steps of:
when $W=E+1$, adjusting pixel clock signal phase for a
next frame; and
redetermining the actual number W of pixel clocks for the
next frame.

18. The method of claim 15, including the steps of:
when $W=E+1$, adjusting pixel clock signal phase by a
selected iterative amount for each of a series of sub-
sequent frames;

determining the actual number W of pixel clocks for each
of the series of subsequent frames; and

storing the actual number W of pixel clocks for each of the
series of subsequent frames;

identifying a subseries of consecutive frames in which
 $W=E$;

selecting a corrected frame from the subseries of con-
secutive frames, the corrected frame being from a
middle portion of the subseries of consecutive frames;

identifying a corrected pixel clock signal phase of the
corrected frame; and

setting the pixel clock signal phase to the corrected pixel
clock signal phase.

19. The method of claim 15, including the step of corre-
lating the expected width of the video image to an expected
number E of pixel clocks.

20. The method of claim 15, including the step of corre-
lating the actual width of the video image to an actual
number W of activated pixels.

* * * * *

21. A method for recovering a correct phase and frequency clock for an analog video signal that is converted into a digital video signal for display on a digital display object having pixels arranged in lines and columns, the analog video signal including an analog video data signal that is operable for raster scanning in lines across a display screen to form consecutive frames of video information, the raster scanning controlled by timing signals that control a line scan rate and a frame refresh rate to produce consecutive frames of video information, comprising:

estimating an expected width of an image producible by the analog video signal;
determining an actual width of an image producible by the digital video signal; and
iteratively adjusting the digital video signal until the actual width equals the expected width.

22. The method of claim 21, further including:

generating a pixel clock signal that samples the analog video signal to convert the analog video signal to the digital video signal; and

iteratively adjusting at least one of frequency and phase of the pixel clock signal to iteratively adjust the digital video signal.

23. The method of claim 22, further including adjusting the frequency of the pixel clock signal before adjusting the phase of the pixel clock signal.

24. The method of claim 21, in which the determining an actual width of an image includes determining a difference between a number of reference clock counts occurring between successive sync pulses associated with the lines of the digital display object and a number of reference clock counts occurring within a blanked data interval between next successive sync pulses associated with a line of the display object.

25. The method of claim 24, in which the number of reference clock counts occurring between successive sync pulses represents for each line of the digital display object an average number of clock counts taken over multiple sync pulses.

Fig. 1a

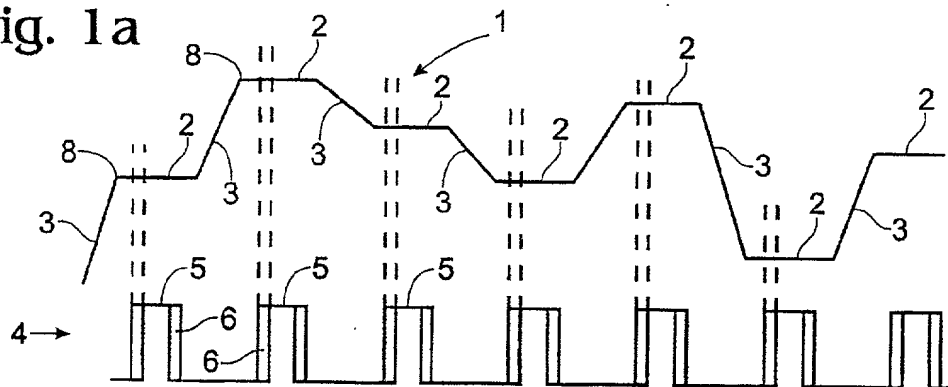


Fig. 1b

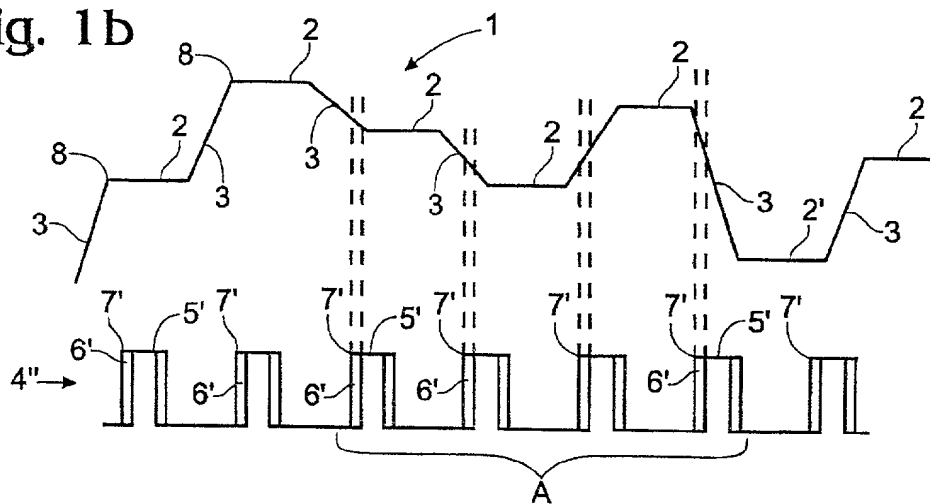
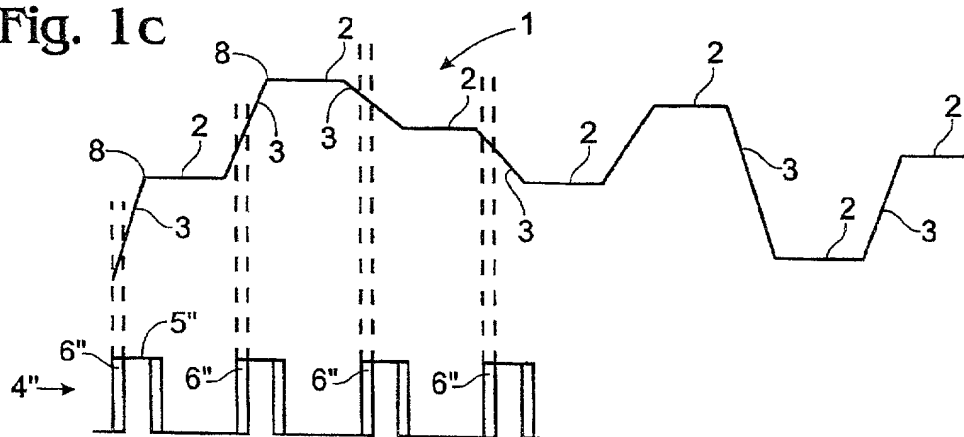


Fig. 1c



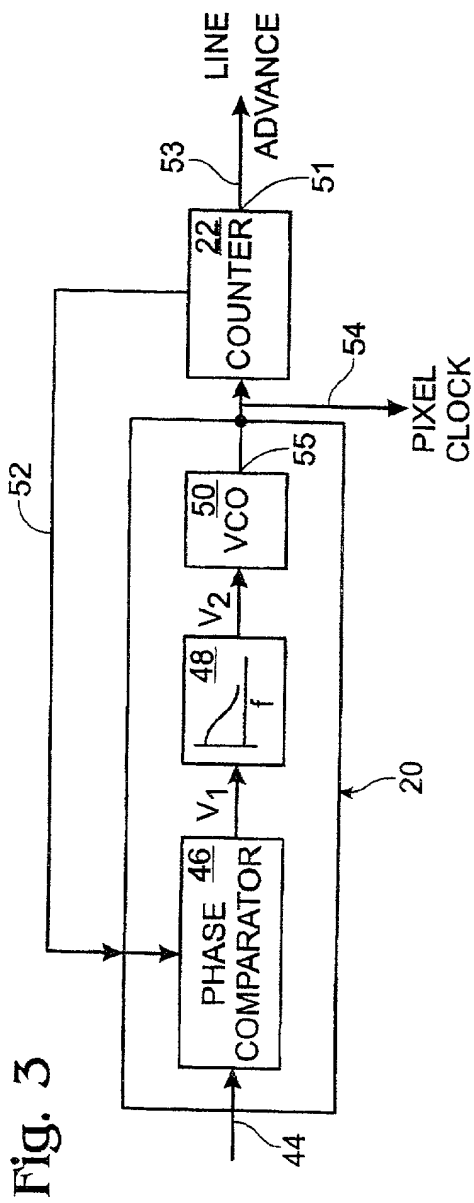


Fig. 5

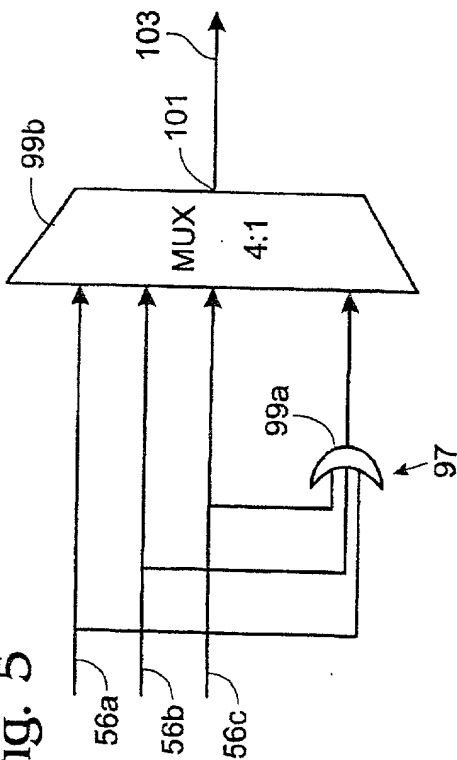


Fig. 1d

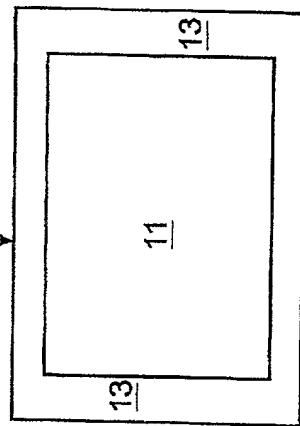


Fig. 4

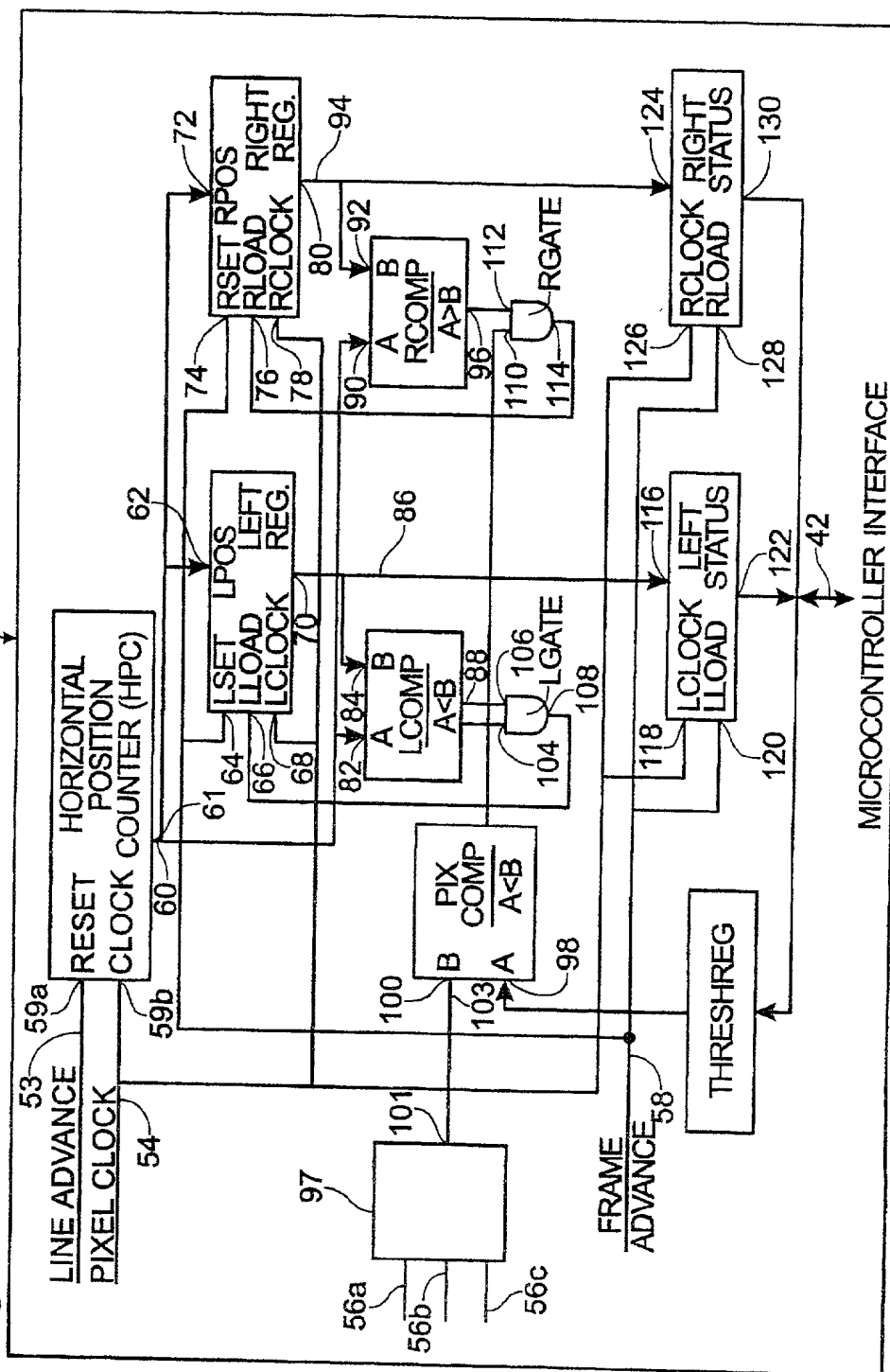
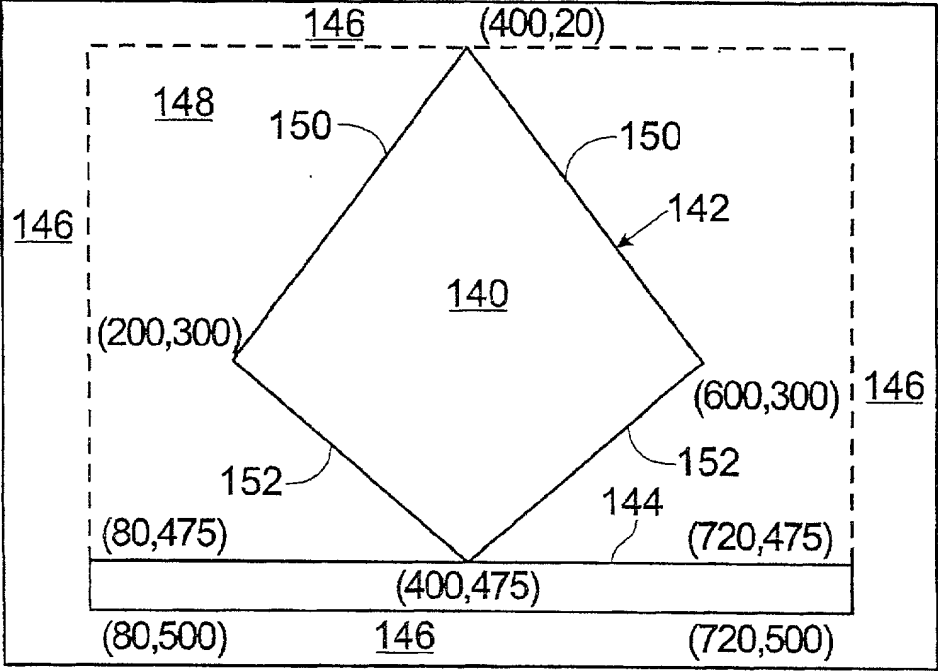


Fig. 6



REISSUE PATENT APPLICATION

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re reissue application of

Group Art Unit:

Michael G. West

Patent No. 5,805,233

Issued: September 8, 1998

For: **METHOD AND APPARATUS FOR AUTOMATIC PIXEL CLOCK
PHASE AND FREQUENCY CORRECTION IN ANALOG TO
DIGITAL VIDEO SIGNAL CONVERSION**

REISSUE APPLICATION DECLARATION
BY THE INVENTOR

TO THE ASSISTANT
COMMISSIONER FOR PATENTS:

As a below named inventor, I hereby declare that:

1. My residence, post office address, and citizenship are stated below next to my name.

2. I believe I am the original, first, and sole inventor of the subject matter which is described and claimed in U.S. Patent No. 5,805,233 ("the '233 patent"), granted September 8, 1998, and for which a reissue patent is sought on the invention entitled METHOD AND APPARATUS FOR AUTOMATIC PIXEL CLOCK PHASE AND FREQUENCY CORRECTION IN ANALOG TO DIGITAL VIDEO SIGNAL CONVERSION, the specification of which is attached hereto.

3. I have reviewed and understand the contents of the above-identified specification, including the claims.

4. I acknowledge the duty to disclose information that is material to patentability as defined in 37 CFR 1.56.

5. I believe that the original patent ('233 patent) is wholly or partly inoperative or invalid, by reason of the patentee's claiming more or less than the patentee had the right to claim in the patent.

6. The invention recovers a correct phase and frequency clock for sampling an analog video signal that undergoes analog-to-digital conversion for display on a digital display object. At least one error on which reissue is based is that certain of the claims (e.g., claims 1-3) of the '233 patent are unnecessarily narrow. Each of these claims recites converting an analog video signal to a digital video signal as an element set forth outside the preamble. These claims suggest preclusion of direct coverage of practice of the invention on a digital video signal converted from an analog video signal that is sampled by the phase and frequency clock recovered by this invention.

7. All errors corrected in this reissue application arose without any deceptive intention on the part of the applicant.

8. I hereby appoint the following attorneys and/or agents to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith:

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9. I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section

Variable	Mean	SD	Min	Max
Age	34.5	10.2	21	55
Gender	0.5	0.5	0	1
Marital status	0.6	0.5	0	1
Education	12.5	1.5	9	16
Income	1500	500	500	3000
Health status	0.8	0.2	0	1
Smoking status	0.3	0.5	0	1
Alcohol consumption	0.2	0.4	0	1
Exercise frequency	0.5	0.5	0	1
Stress level	0.7	0.3	0	1
Depression score	0.4	0.4	0	1
Life satisfaction	0.6	0.3	0	1
Quality of life	0.7	0.2	0	1
Healthcare utilization	0.5	0.5	0	1
Health insurance	0.9	0.1	0	1
Healthcare access	0.8	0.2	0	1
Healthcare cost	1000	300	500	2000
Healthcare quality	0.7	0.2	0	1
Healthcare satisfaction	0.6	0.3	0	1
Healthcare utilization	0.5	0.5	0	1
Healthcare access	0.8	0.2	0	1
Healthcare cost	1000	300	500	2000
Healthcare quality	0.7	0.2	0	1
Healthcare satisfaction	0.6	0.3	0	1

Signature: _____ Date _____

Citizenship: United States of America
